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The role of endangered oak (Quercus spp.) savanna characteristics in supporting red-headed woodpecker (Melanerpes erythrocephalus L.) populations

Kimberly J. Zralka
Olivet Nazarene University, kimberlyz@ameritech.net

THE ROLE OF ENDANGERED OAK (*QUERCUS* SPP.) SAVANNA CHARACTERISTICS IN SUPPORTING RED-HEADED WOODPECKER (*MELANERPES ERYTHROCEPHALUS* L.) POPULATIONS

By

Kimberly J. Zralka

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ABSTRACT

Declines in animal populations worldwide are of critical conservation concern. However, without an understanding of optimal habitat preference, it is often difficult to determine what factors are driving these losses. Red-headed woodpecker (*Melanerpes erythrocephalus* L.) populations have declined by over 70% in the last 50 years, yet in some areas the birds seem to maintain stable populations. The aim of this study was to empirically test the effects of various habitat factors on red-headed woodpecker presence and abundance in both the summer and winter seasons. As oak acorns are a critical food source for this bird, we were particularly interested in whether the oak species (*Quercus* spp.) present in savanna environments (an endangered ecosystem in the Midwestern United States) affect woodpecker presence and abundance, as this has not been tested to our knowledge. After conducting 414 point-count surveys and habitat analysis at five sites throughout northeastern Illinois, generalized linear and multiple regression models using backwards elimination were used to show how habitat factors affected presence and abundance of red-headed woodpeckers. Our models indicated that decreasing canopy cover, increasing dead limbs, increasing red oak group trees, and decreasing white oak group trees at a site were significant factors in predicting woodpecker presence and abundance during the summer months. However in winter, our models indicated that mainly tree size, and potentially number of snags, number of dead limbs, and percent canopy cover play a role in predicting red-headed woodpecker habitat selection. These results confirm and expand upon previous studies, suggesting that mature

oak savanna environment is important to the success of red-headed woodpecker populations. Our findings that a greater number of red oak group trees, but a smaller number of white oak group trees, may be positively related to woodpecker abundance at a site is of interest, as this may indicate that the optimal habitat requirements of red-headed woodpecker populations are more specific than previously thought. Together, these factors should help inform managers in conservation planning for this iconic species.

INTRODUCTION

A Threatened Species: The Red-headed Woodpecker

In almost all areas around the world today, animal species are facing extinction threats. One of the most commonly reported threats is habitat loss. In today's world, natural lands are being encroached upon by urbanization, agriculture, and industry (Dobson et al 1997, Ceballos et al 2017). Some species are able to adjust and thrive in these environments. However, the majority of species struggle with the ever-changing landscape (Ceballos et al 2017). Many are even considered to be reliant on their native habitat and cannot populate other areas (Dobson et al 1997, Ceballos et al 2017). This is thought to be the case for the red-headed woodpecker (*Melanerpes erythrocephalus* L.) (Brawn 2006).

Once prominent throughout the region, these birds have seen a decline of over 70% in the last 50 years alone (Koenig et al 2017). The red-headed woodpecker is targeted as high conservation priority in more states than any other woodpecker species (Shunk 2016) as they are currently listed as Near Threatened by IUCN Red List ("BirdLife" 2018) and are on the Yellow Watch List of the State of the Birds Report as a National Species of Conservation Concern ("State" 2016). Although there are a number of theories as to their decline (Koenig et al 2017), habitat degradation and loss are thought to be the main contributors (Dallas 2015, Holoubek and Jensen 2015).

Habitat Utilization & Loss

Red-headed woodpeckers are thought to be dependent on the oak savanna habitat (Brawn and Blood 2004, Brawn 2006, Grundel and Pavlovic 2007, Dallas 2015). This type of ecosystem combines open, prairie-type grassland with a scattered oak canopy (10-70% canopy cover) (Asbjornsen et al 2007, Brawn 2006, Wilcox et al 2005). Oak savanna has been historically considered vital to the success of red-headed woodpecker populations, as the grasses provide areas for the birds to gather flying insects using their unique flycatching ability, and the tree cover allows the birds areas to cache acorns and build nests (Brawn & Blood 2004, Dallas 2015, Shunk 2016). If an area is too open, red-headed woodpeckers will not have spaces to nest and cache food for winter, and the lack of any cover subjects red-heads to increased predation risks from *Accipiter* spp., such as cooper's (*Accipiter cooperii*) and sharp-shinned (*Accipiter striatus*) hawks (Koenig et al 2017). Unfortunately, less than 0.01% of Midwest oak savannas remain today, mainly due to human land development and a lack of regular fire regimes throughout the landscape (Dallas 2015). Black oak (*Quercus velutina*) savanna habitat specifically, though once abundant, is now rare in the Midwest (Dallas 2015, Holoubek and Jensen 2015). However, previous work has indicated that red-headed woodpecker populations have remained somewhat stable in the remaining patches of high-quality black oak savanna that still exist in northwestern Illinois (Brawn and Blood 2004).

Despite being labeled as the "savanna bird," (Brawn 2006), the red-headed woodpecker has historically been known to interact with human society, even going so far as to commonly nest in telephone poles and store caches in fence posts (Beal 1911, Macroberts 1975, Rodewald et al 2005, Frei et al 2013). With these two contrasting observations and the continual decline in red-headed woodpeckers today, research to better understand which specific habitat characteristics are most important to overall red-headed woodpecker population success is key.

Habitat Factors & Red-headed Woodpecker Habitat Selection

There are a number of studies that have been conducted previously exploring the relationship between red-headed woodpecker habitat factors and red-headed woodpecker abundance, although a number of these studies mainly focus on the effects of habitat on red-head nesting site selection and nesting success (Conner and Adkisson 1977, Brawn and Blood 2004, Rodewald et al 2005, King et al 2007, Frei et al 2013, Anderson and LaMontagne 2016). This research indicates that characteristics generally associated with the oak savanna environment, such as a lower percentage of canopy cover, the presence of snags (or dead, standing trees), and the presence of dead limbs, are important factors (Brawn and Blood 2004, Rodewald et al 2005, King et al 2007, Frei et al 2013).

In this study, specific emphasis was placed on the impact of oak species (*Quercus* spp.) composition. Oaks are a major component of most Midwest savanna environments, and the acorns they produce are a vital component to the winter diet of red-headed woodpeckers. In our study, oak species were broken down into the distinct red oak group, or subgenus *Erythrobalanus* or *Lobatae* (black, *Q. velutina*, red, *Q. rubra*, etc.) and white oak group, or subgenus *Leucobalanus* or *Quercus* (bur, *Q. macrocarpa*; white, *Q. alba,* etc.) trees. Since the red oak and the white oak groups are very distantly related phylogenetically (Kapelle 2006, Hipp et al 2013), we expected to potentially see a difference in the way each affected red-head habitat selection as well. To our knowledge, the relationship between red-headed woodpecker abundance and this oak group distinction had not been tested. In addition, this study aimed to determine if seasonal differences exist in red-headed woodpecker habitat selection. Although some red-head wintering behavior has been detailed in the past (Kilham 1958, Moskovitz 1978) to our knowledge woodpecker habitat selection during the winter season has not been studied in the Midwest, and other studies of this are limited (Macroberts 1975). Habitat composition can change drastically from season to season in the Midwest, so there is potential that this may effect red-head abundance in different areas of a site. In addition, while some populations of red-headed woodpeckers remain in the Midwest year-round, woodpeckers from other parts of the country do migrate seasonally (Bock & Lepthien 1975). The seasonal influx and outflux of these migrants may yield different population densities during the summer and the winter seasons.

Study Objectives

The objective of this study was to empirically test the effects of various habitat factors on red-headed woodpecker population density throughout the summer and winter seasons in northeastern Illinois. These characteristics included oak species composition, percent canopy cover, number of dead limbs, number of snags, and tree size. We hypothesized that the characteristics associated with the red-headed woodpecker's native mature oak savanna environment, such as a low percent of canopy cover, a greater number of snags and dead limbs, a greater number of large trees, and a higher percent of any oak species present at a site, will result in a higher presence and abundance of red-headed woodpeckers overall, in accord with previous research. We also predicted that the same characteristics that were significant to red-headed woodpecker presence and abundance in the summer season would be significant in the winter season as well. Overall, a greater understanding of habitat composition will allow us to better create more successful conservation management plans for both this threatened bird species and this endangered ecosystem.

METHODS

Study Sites

Research was conducted at five different sites throughout northeastern Illinois. These included Braidwood Dunes and Savanna Nature Preserve (41°15'29.0"N 88°11'37.9"W), Goodenow Grove Nature Preserve (41°24'03.6"N 87°36'20.4"W), Hooper Branch Savanna Nature Preserve (41°00'26.9"N 87°33'16.2"W), Mskoda Land and Water Reserve (41°04'47.5"N 87°39'43.7"W), and Pembroke Savanna Nature Preserve (41°04'27.9"N 87°38'26.6"W) (**Fig. 1**). While each site varied in habitat composition, red-headed woodpeckers were known to be present. A single transect composed of 7-11 observation points (depending on site size) spread 200 meters apart was established at each preserve.

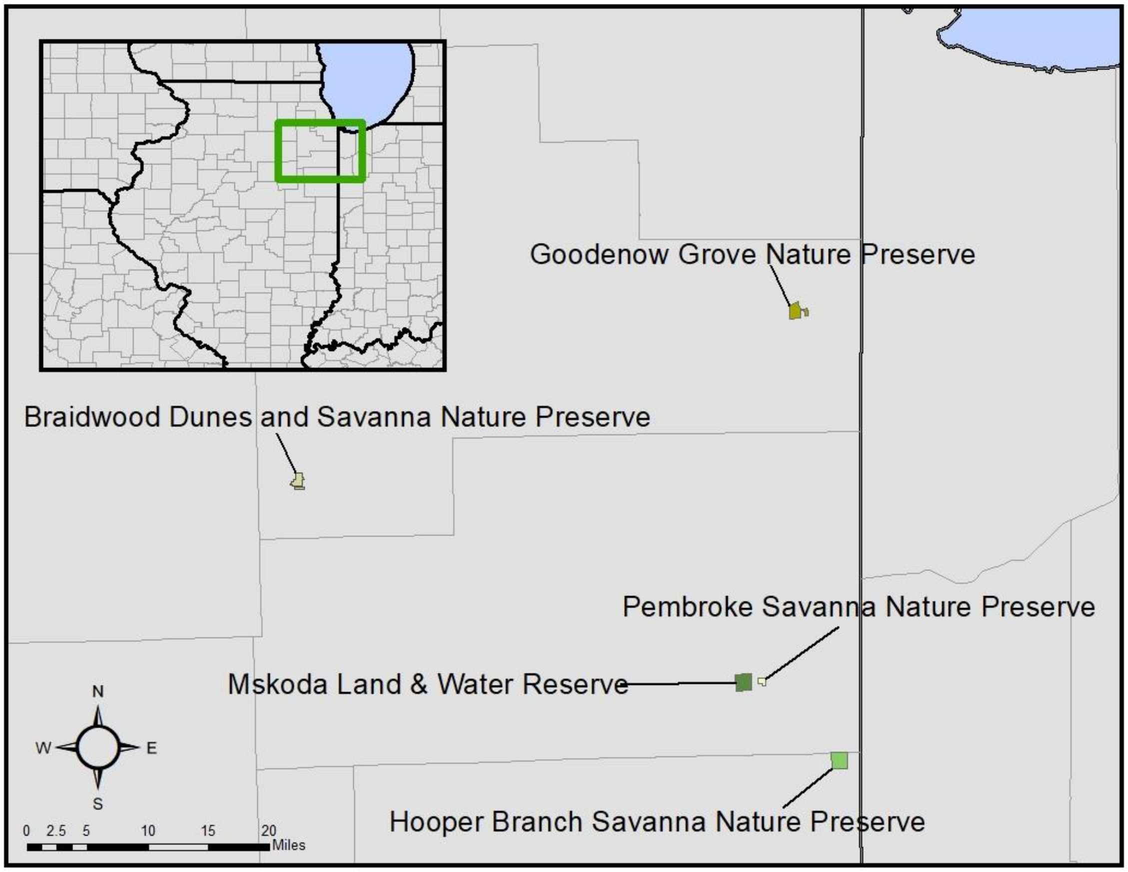

Figure 1: Map of research sites. credit: Kimberly J. Zralka

Red-headed Woodpecker Abundance Surveys

At each site, red-headed woodpecker populations were assessed via a point count censusing technique with the accompaniment of red-headed woodpecker call playback, to increase probability of detection. During a single survey, five-minute observation periods took place at each observation point. First, the researcher stood in silence, listening and observing the area around the point for red-head calls and sightings for two minutes. Then, a prerecorded red-headed woodpecker call (accessed via Macaulay Library) was projected in all directions via a wireless speaker held by the researcher for 30 seconds. This was followed by one minute of silent observation in the same manner as used previously. These 30 seconds of call playback and one minute of silent observation were then repeated once more, before the researcher moved on to the next point, where the process was repeated. The transects were surveyed five times throughout the summer season (May-August 2017-18), and four times during the winter season (January-February 2018-19).

Habitat Analysis

Habitat analysis was conducted at each site using a variation of the BBIRD protocol (Martin et al 1997). At each observation point of every site's transect, four circular plots were laid out for analysis (one plot centered on the point and three plots located 50 meters from the center of the observation point, spread around the point by about 120°). At each of these plots, string was laid out in each of the cardinal directions, creating a circle 11.3 meters in radius. The size and species classification of each tree present in the plot was documented, as well as the total number of dead limbs (≥30cm long and ≥16cm in diameter) and snags (≥16cm DBH and ≥2m tall) in the plot. Size was classified by measuring the diameter at breast height (DBH) of the trees, further classified into small (DBH ≥8cm-23cm), medium (DBH 24cm-38cm), or large (DBH ≥39cm) classification. Upon analysis, each tree size classification was assigned a value (1, 2, & 3 from small to large accordingly), and these were tallied and then divided by the total number of trees at the point, resulting in its tree size index. In addition, percent canopy cover was documented from the center of each plot with the use of a densitometer.

Statistical Analysis

The woodpecker abundance for each survey point was averaged for the 2-3 surveys per season, and woodpecker presence was organized binomially with a “1” representing woodpecker presence at at least one of the surveys at a point, and a “0” representing no woodpecker presence. The data were then analyzed with R analysis software. Generalized linear mixed effects modeling with a binomial distribution was used to determine how different habitat factors influenced one another in predicting woodpecker presence. Multiple linear regression models in a mixed effects framework were used to show how different habitat factors influenced one another in predicting woodpecker abundance. Square root transformation of the dependent variable, woodpecker abundance, was needed to fulfill model assumptions homoscedasticity and normality of errors after visually inspecting residual plots. Year and site were included as random effects in both generalized linear models and multiple linear regression models, and model assumptions were checked with residual plots. Model selection relied upon backwards elimination. Factors with the highest P-values were removed sequentially and Akaike information criterion (AIC) was used to determine the best model. Factors with P-values less than 0.05 were determined to be significant.

RESULTS

Red-headed Woodpecker Site Surveys

Across 5 sites, 46 points were surveyed 414 times: 3 times each during the summer of 2017 and 2 times each during the summer of 2018 (n=230). Each point at each site was surveyed twice during January-February 2018 and twice during January-February 2019 (n=184). On average, red-headed woodpeckers were about twice as abundant during the summer as compared to the winter season in northeastern Illinois (p=0.003) (**Fig. 2**).

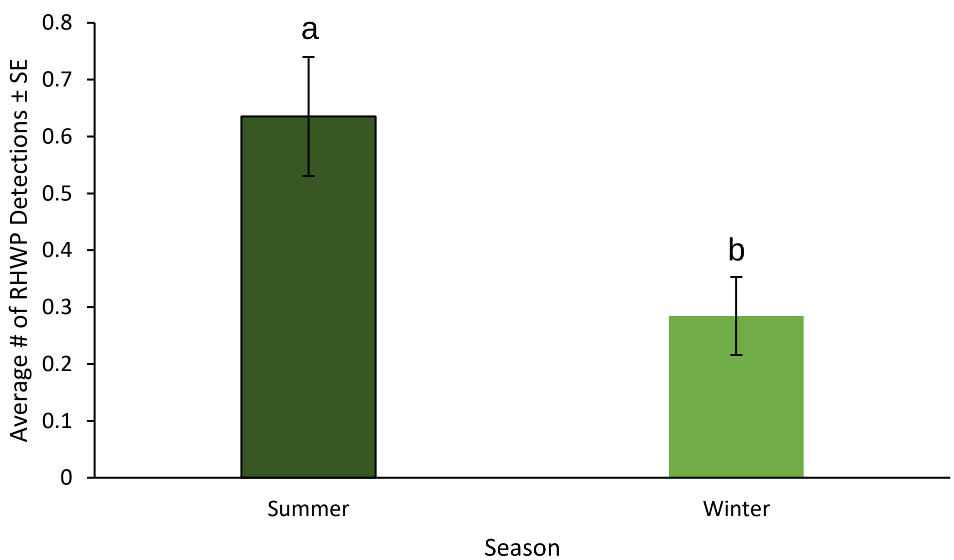

Figure 2. Average red-headed woodpecker detections across all sites during the summer 2017-18 (n=230) and winter 2018-19 (n=184) seasons. a & b represent significantly distinct values.

Red-headed woodpeckers were successfully detected at each site during the summer and winter seasons (**Fig. 3**). During the summer, the average number of detections per transect point at the Braidwood and Goodenow sites was generally less than the average detections at Hooper Branch, Mskoda, and Pembroke. During the winter, Hooper Branch and Pembroke (but not Mskoda) were still some of the most red-headed woodpecker abundant sites and Braidwood and Goodenow were some of the least red-head abundant sites (**Fig. 2**).

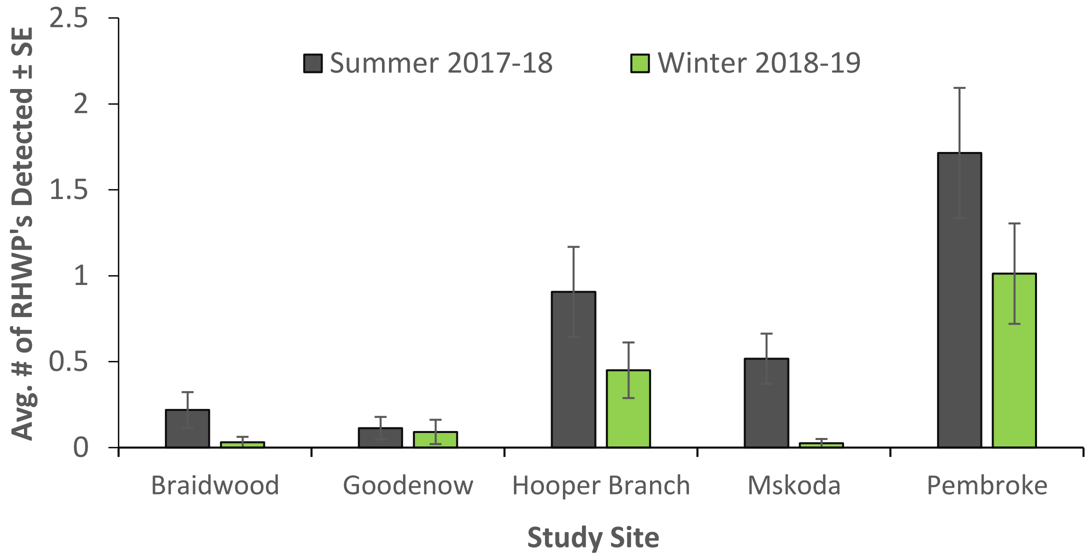

Figure 3. Average red-headed woodpecker detections per transect point during the summer (2017-18) and winter (2108-19) seasons.

Summer Red-headed Woodpecker Presence and Abundance

Backwards elimination using a mixed effects generalized linear model yielded different models predicting woodpecker presence at a site in summer versus winter. Canopy cover was negatively correlated with red-headed woodpecker presence. Total number of dead limbs was positively correlated with woodpecker presence, as was percent of trees in a plot that were in the red oak group. In the summer season, statistically insignificant factors eliminated from the model included snags, percent white oak group trees (i.e. bur oak (*Q. macrocarpa)* and white oak (*Q. alba)*), and tree size (**Table 1**).

Table 1. *Factors resulting in the best model describing woodpecker presence during the summer season in northeastern Illinois using a generalized linear mixed effects model with a binomial distribution. Factors eliminated from the model included snags, tree size, and percent white oak.*

Factor	**z-value**	**p-value**
% Canopy Cover	-2.78	0.00545
Total Dead Limbs	2.09	0.03646
% Red Oaks	2.48	0.01298

Multiple linear regression allowed us to determine if more than one factor predicts woodpecker abundance. The best predictors of red-headed woodpecker abundance during the summer were fewer trees, more dead limbs, and fewer white oak group trees, (**Table 2**). Canopy cover was negatively correlated with red-headed woodpecker abundance. Total number of dead limbs was positively correlated with woodpecker abundance. Percent white oak was a marginally significant factor, with a p-value of 0.052. Removing percent white oak from the model resulted in a worse AIC score, indicating that a decreasing percent of white oak group trees does play a role in predicting red-headed woodpecker abundance. Thus, we included this factor to obtain the most predictive model. In the summer, statistically insignificant factors eliminated from the model included snags, tree size, and percent red oak group trees (i.e. black *Q. velutina*, and red, *Q. rubra*).

Table 2. *Factors resulting in the best model describing woodpecker abundance during the summer season using a multiple linear regression and backward elimination with site as a random effect. Factors eliminated from the model included snags, tree size, and percent red oak.*

Factor	df	t-value	p-value
% Canopy Cover	79	-2.53	0.0134
Total Dead Limbs	79	2.44	0.0170
% White Oaks	79	-1.97	0.0520

Winter Red-headed Woodpecker Presence and Abundance

Determining the model to best predict woodpecker presence in winter proved to be more complex, as five models with comparable AIC scores were produced with varying significant factors (**Table 3**). Overall, the presence of large trees appeared to be the best predictor of winter woodpecker presence, as this factor remained significant or marginally significant across all five models. Canopy cover, number of snags, and number of dead limbs were also included as influential model factors, however they had varying degrees of significance across the different models.

Table 3. The factors of the five models yielding the best (lowest) AIC scores for predicting red-headed woodpecker presence during winter 2018-19. (** indicates p-value <0.05, & * indicates p-value <0.1, no symbol indicates p-value >0.1).

Model Factors	**AIC**
# of Dead Limbs*, Tree Size*	87.3
# of Snags, # of Dead Limbs, Tree Size*	87.5
% Canopy Cover, # of Snags, Tree Size*	87.7
% Canopy Cover*, Tree Size**	88.3
% Canopy Cover, # of Snags, # of Dead Limbs, Tree Size*	89.0

The best model predicting red-headed woodpecker abundance during the winter season included the number of dead limbs and tree size. Number of dead limbs was negatively correlated with woodpecker abundance, Tree size was positively correlated with woodpecker abundance (**Table 4**). In the winter, statistically insignificant factors eliminated from the model included percent canopy cover, number of snags, percent red oak group trees, and percent white oak group trees.

Table 4. *Factors resulting in the best model describing woodpecker abundance during the winter season using a multiple linear regression and backward elimination with site as a random effect. Factors eliminated from the model included percent canopy cover, number of snags, percent red oak, and percent white oak.*

Factor	**df**	**t-value**	**p-value**
# of Dead Limbs	80	-2.11	0.0371
Tree Size	80	2.28	0.0253

DISCUSSION

Tree species composition played a significant role in creating the best models during the summer season. In particular, a decreasing percentage of white oak group trees and an increasing percentage of red oak group trees were important factors in predicting red-head presence and abundance (**Tables 1&2**). This suggests that red-headed woodpeckers may be much more reliant on a specific clade of oak trees (i.e. trees of the red oak group) than previously thought. Oak savanna habitats characterized by a greater percentage of white oak group trees may not be as suitable for hosting as successful a population of red-headed woodpeckers as those characterized by a greater percentage of red oak group trees. The reason for this preference for red oaks is unclear and deserves further research. Tree structure, acorn size, and acorn nutrition all warrant further investigation as to why this trend emerges. However, these new findings emphasize the importance of the conservation of the remaining stands of black oak savanna habitat that do exist in the Midwest.

The number of red-headed woodpecker detections per survey point at Braidwood and Goodenow was lower than those of Hooper Branch, Mskoda, and Pembroke (**Fig. 3**). As each site differed greatly in habitat composition, this is likely a major factor as to why these site groupings emerged from the data.

The difference in the average number of red-headed woodpeckers per observation point during the summer and winter seasons (**Fig. 3**) shows that seasonality does indeed play a significant role in red-headed woodpecker abundance. A decline in abundance across all sites in the winter suggests that some woodpeckers migrate to other locales. Another potential contributing factor may be that red-headed woodpeckers require different resources for survival in the winter than those needed during the summer. Overall, these results show that the effect of seasonality on habitat selection of the red-headed woodpecker warrants further investigation.

In the summer, red-headed woodpecker presence and abundance had a direct negative correlation with percent canopy cover (**Tables 1&2**), and this seemed to potentially influence their presence in the winter as well (**Table 3**). These results support past research on the red-headed woodpecker use of habitat, which has shown that these birds are dependent on the oak savanna environment (Brawn and Blood 2004, Brawn 2006, Grundel and Pavlovic 2007, Dallas 2015, Holoubek and Jensen 2015). The Hooper Branch, Mskoda, and

Pembroke sites were mostly characterized by low percentages of canopy cover, supporting why these sites had more detections of red-heads overall.

Total number of dead limbs was also significant in predicting both red-head presence and abundance in the summer season (**Tables 1&2**), supporting work of others (Rodewald et al 2005). Dead limbs are thought to be important for the reproductive success of these woodpeckers, as they provide locations for the birds to construct nest holes (Rodewald et al 2005, Kilgo & Vukovich 2012, Frei et al 2013). In addition, dead limbs are known to provide perches for red-heads to use while flycatching for insects (Kilham 1958), making them an important tool in food gathering. These results indicate that red-headed woodpecker abundance may be much more dependent on specific habitat factors than originally thought. In the winter however, the birds are not engaging in flycatching behaviors, and thus in no need of dead limbs for perches. It is unclear however why fewer dead limbs promoted woodpecker abundance. Perhaps this is due to factors related to the types of trees or habitats that have more dead limbs. This finding should be investigated further.

Total number of snags was not significant during the summer season (**Table 2**). This is consistent with some previous studies (Kilgo and Vukovich 2012), yet in opposition with others (Ingold 1989, Conner et al 1994, King et al 2007, Dallas 2015). Some studies have indicated that number of snags is an important factor in red-headed woodpecker success in an area, as they provide areas for red-heads to cache acorns and create nest holes (Ingold 1989, Brawn and Blood 2004, Rodewald et al 2005). Yet others have found that red-heads prefer to nest in dead limbs of living trees (Rodewald et al 2005, Kilgo & Vukovich 2012), indicating that snags may not be as significant to red-headed woodpeckers as originally thought. This disparity warrants further research.

Whereas it had no impact in the summer season, total number of snags was an influential factor in predicting red-headed woodpecker abundance during the winter season (**Table 3**). During the summer season when insects, not caches, are the main food source for these birds (Beal 1911, Shunk 2016), snags would be less important than they would be in the winter season. This difference between the summer and winter seasons further underscores that seasonality plays a significant role in determining red-headed woodpecker habitat selection. Snags may play a greater role in the wintering behavior of red-heads than has previously been thought, and this warrants further investigation.

One of the most important factors in predicting red-head abundance in the winter season was tree size (**Table 3**). Our data showed that an area with a greater tree size index, i.e. more large diameter trees, yielded a greater number of red-headed woodpeckers in the winter season. As larger trees would provide more cover for the woodpeckers during the winter season when no other vegetation is present, a greater number of large trees makes sense in boasting a greater abundance of red-heads. This would not be as important during the summer season, when there is so much other vegetation providing cover. In addition, a greater number of large trees would yield a greater production of acorns, as oaks need to be mature in order to produce acorns. Acorns provide red-headed woodpeckers with their main food source during the winter season

(Kilham 1958, Moskovitz 1978, Anderson and LaMontange 2016), so this would yield a larger wintering food stock for the birds overall. Also, a greater number of large trees would yield a greater number of potential caching locations for acorns. This again shows how influential season can be in affecting the red-headed woodpecker habitat selection. To our knowledge, this is the first study to show the importance of large mature trees on winter red-headed woodpecker habitat preferences.

These results of this study generally supported the hypothesis that the characteristics associated with the red-headed woodpecker's native oak savanna environment would result in a higher abundance of these birds. This study further shows that overwintering birds may depend on the presence of large mature trees. Overall, our data suggests that the ideal habitat for red-headed woodpeckers would include a large number of large red oak group trees with plenty of dead limbs for summer flycatching, and a low percentage of canopy cover. With the continuing loss of this endangered habitat in the Midwest, conservation efforts are needed to sustain the red-headed woodpecker. The results of this study can be used by conservation organizations to allow them to better shape their land management plans and policies in the future.

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